The variation of nutrient concentration in the rhizosphere of larch and ash in mixed and monoculture stands

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Abstract: Soil samples were taken from rhizosphere zone and off-rhizosphere zone of ash (*Fraxinus mandshurica* Rupr.) and larch (*Larix olgensis* Henry) in mixed and monoculture stands, and the nutrient concentration of N, P, and K was analyzed to study the effect of nutrients variation on yield improvement in the mixed stand. The result showed that: 1) The stand level total soil N concentration and available N in the mixed stand was similar to that in the monoculture stand of ash, but higher than that in monoculture stand of larch. The total N and available N concentration in rhizosphere soil of ash in the mixed stand was similar to that in the monoculture stand of ash, but the available N concentration in rhizosphere of larch in mixed stand was much higher than in its monoculture. 2) The stand level total P, total K concentration in the mixed stand was similar to that in monoculture stands of both species, but available P and K was more concentrated in the mixed stand than in the monoculture stands of ash. The rhizosphere available P and K of ash in the mixed stand was 44.1% and 13.5% (for the 9-yr-old stands) and 79.6% and 25.6% (for the 21-yr-old stands) higher than that in its monoculture. The improvement of soil P and K availability in the mixed stand is concluded.

Key words: Ash; Larch; Mixed plantation stand; Rhizosphere; Soil nutrition

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Introduction

Ash (*Fraxinus mandshurica* Rupr.) is an important commercial tree species in Northeastern China. Slow growing is the problem with its monoculture plantation. The yield improvement effect from association of larch within the mixed stand has been reported by many researchers (Guo 1991a; Chen *et al.* 1991). The mechanism underlying the effect has driven many researches (Zhang *et al.* 2001; Wang *et al.* 1994; Guo *et al.* 1991b). Some research results suggested that the improved overall soil nutrients availability in the mixed stand was important for the enhanced growth rate of ash trees (Wang *et al.* 1994; Guo *et al.* 1991b). Since nutrients uptaken by plants are mainly from the rhizosphere, the available nutrients in bulk soil over a distance can be regarded as temporally unavailable (Zhang and Cao 1992; Qin and Liu 1989). The improvement of rhizosphere nutrient availability is more meaningful for the growth enhancement of trees. In this study, the soil samples of both the rhizosphere soil and off-rhizosphere soil in the mixed and monoculture stands of ash and larch were taken and analyzed to unveil the yield improvement mechanism in the mixed stand.

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Site description

This study was conducted in plantation stands at two sites, i.e. Jianlagou Research Forest of Northeast Forestry University and Jiangshanjiao Research Forest of Forestry Academy of Heilongjiang Province. The two sites are located at the Laoyeling Ridges of Changbai Mountains and 300 km apart. They share features of landscape, climate, dominant vegetation and regional soil. The stands studied differ in features listed in Table 1.

Table 1 Features of the plantation stands at the two locations

Site	Soil type	Stand age /a	Initial spacing /m^2	Spatial arrangement of trees of the two species in the stand
Jianlagou	Dark Brown Forest Soil	9	1.5×1.5	Monoculture stands of ash and larch; strip mixture(ash:larch=3:5)
Jiang-shanjiao	Meadow Soil	21	1.5×2.0	Monoculture stands of ash and larch; Row mixture(ash:larch=1:1)

Data collection

On representative sites in the monoculture stands of ash and larch, and the mixed stand, a 0.1-hm^2 plot was set up. Thirty off-rhizosphere samples were taken along the diagonal line mechanically. Samples were taken from two soil layers, i.e., 0-20 cm, and 20-40 cm, in July, 1996 at the two locations. Fifteen stems of normally growing trees were selected, and the soil adhering to the roots of the trees in the soil layer of 0-20 cm was collected as the rhizosphere

soil sample.

The samples were kept at 5°C before sending to the lab. After air-drying, the samples were analyzed to determine the concentration of total N, P, K, and available N, P, and K. The procedures employed in soil analysis were adopted from National Standard Bureau of P. R. China. (1988).

Results

Soil nutrients concentration in different stands

Soil N

In the 21-yr-old stands, the highest concentration of total N and available N in soil was found in monoculture stand of ash, and the lowest in the soil in the monoculture stand of larch. Same trend was found within the 9-yr-old stands, but the difference was not as large as that in the 21-yr-old stands. (As showed in Table 2)

Soil P

Total P concentration of soil in the 9-yr-old stands was not obviously different between ash, larch, and mixed stands (Table 2). For the 21-yr-old stand, the total P concentration of 0-20 cm soil in the monoculture stand of larch was similar to that in the mixed stand, but that in monoculture stand of ash was 15% higher than in the mixed stand. In the 9-yr-old stands, the available P concentration in 0-20 cm soil layer was higher in monoculture stand of larch and the mixed stand than in ash stand. Same trend was also found with the 21-yr-old stands but the difference was much greater. The available P concentration in the 21-yr-old mixed stand was 15.5 $\mu g \cdot g^{-1}$, with an increase of 40% comparing to that (11.0 $\mu g \cdot g^{-1}$) of monoculture stand of ash. This result contravenes the result of total P, suggesting that tree species may dominate the availability of P in forest soil, and probably larch is more able to increase the availability of soil P.

Soil K

No significant variance was found in total K concentration for the three stands at both locations. (Table 2) The lowest available K was found with the ash stand at both locations. The available K in 0-20 cm soil layer in the 21-yr-old monoculture stand of larch was 13.9%, 25.4% higher than that in the mixed stand and the ash stand, respectively. This suggests the variation of available K follows the same trend for available P, which is also attributed to the effect of tree species.

Table 2. N, P, and K concentration in rhizosphere and off-rhizosphere soil in different stands

Stand age (a)	Stand	Sampling position		Total N (%)	Available N (μg/g)	Total P (%)	Available P (μg/g)	Total K (%)	Available K (μg/g)
9	MSL	Rhizosphere	0~20	0.726	895.1	0.124	30.1	1.163	270.2
		Off- rhizosphere	0~20	0.660	787.4	0.121	10.1	1.470	193.4
		Off- rhizosphere	20~40	0.232	272.7	0.096	7.7	1.580	123.1
	Mixed	Larch-rhizosphere	0~20	0.760	898.5	0.127	19.3	1.124	207.3
		Ash-rhizosphere	0~20	0.857	926.3	0.141	19.6	1.015	259.1
		Off- rhizosphere	0~20	0.674	812.9	0 127	10.4	1.366	177.0
		Off- rhizosphere	20~40	0.265	313.6	0.080	7.7	1.576	114.2
	MSA	Rhizosphere	0~20	0.845	867.1	0.121	13.6	1.574	228.8
		Off- rhizosphere	0~20	0.684	824.6	0.121	9.5	1.372	175.3
		Off- rhizosphere	20~40	0.271	381.4	0.098	8.2	1.575	93.4
21	MSL	Rhizosphere	0~20	0.717	649.3	0.177	29.1	1.253	359.1
		Off- rhizosphere	0~20	0.671	516.9	0.177	15.6	1.345	256.3
		Off- rhizosphere	20~40	0.366	265.0	0.156	6.6	1.397	166.4
	Mixed	Larch-rhizosphere	0~20	0.812	928.3	0.187	44.9	1.287	442.5
		Ash-rhizosphere	0~20	0.847	971.9	0.176	25.5	1.294	312.9
		Off- rhizosphere	0~20	0.765	803.0	0.175	15.5	1.510	225.0
		Off- rhizosphere	20~40	0.376	422.8	0.169	7.8	1.562	164.3
	MSA	Rhizosphere	0~20	0.896	953.0	0.206	14.2	0.993	249.2
		Off- rhizosphere	0~20	0.775	837.9	0.202	11.0	1.124	204.4
		Off- rhizosphere	20~40	0.369	465.5	0.173	7.5	1.158	134.5

Remark: MSL means monoculture stand of larch; MSA means monoculture stand of ash; Mixed means mixture of ash and larch;

Rhizosphere nutrient concentration in different stands

Rhizosphere Soil N

Total N concentration of rhizosphere soil for both ash and larch species was higher than that of off-rhizosphere soil, and the difference was between 6%-15%. The highest value was found with rhizosphere of ash. Similar trend was found with available N.

The available N concentration in rhizosphere soil of ash did not differ between the ash stand and the mixed stand. The available N concentration in larch rhizosphere in the mixed stand was significantly higher than in the larch stand. In the 21-yr-old stands, the available N concentration of larch rhizosphere in the mixed stand increased by 43% compared with that of larch stand. (649.3 vs. 928.3 μg/g soil)(Table 2)

Rhizosphere Soil P

The total P concentration in rhizosphere soil of the two species was basically the same as in the off-rhizosphere soil with only few exceptions. P is usually easily fixed by soil chemical process, with poor mobility. Deficiency of P in rhizosphere zone is common because of root uptake. Our result contravenes this general trend. The reason is attributed to the existence of large microbe population.

The available P concentration of rhizosphere was higher than that of off-rhizosphere for both ash and larch, particularly for larch. The available P concentration of rhizosphere for larch was 2-3 times that for off-rhizosphere, in contrast to 30%~40% higher for ash. The dramatic increase of available P within the rhizosphere of both species comparing to that in off-rhizosphere suggests that P is activated within rhizosphere. And the ability of P activation of larch is better than that of ash.

Rhizosphere Soil K

For both ash and larch species, the total K in rhizosphere soil was lower than that in off-rhizosphere soil, with the exception of 9-yr-old ash stand. The transportation of K to rhizosphere zone depends on diffusion. The deficiency of K in rhizosphere zone is attributed to the low diffusion rate of K. Nevertheless the available K in rhizosphere soil is significantly higher than in off-rhizosphere soil for all stands. In the 21-yr-old stands, available K of rhizosphere soil for larch and ash was 40%-97%, 22%-39% higher than that of off-rhizosphere. The K element activated in rhizosphere of larch is more than in that of ash. The available K concentration in rhizosphere soil of ash in the mixed stands is higher than in that of ash stand, and the extent of increase was 13.5%, and 25.6% for the 9-yr-old stands and 21-yr-old stands, respectively. This result suggests that the availability of K in rhizosphere soil is improved in the mixed stand comparing to that in ash stand. This is an advantage for the growth of ash in the mixed stand.

Discussion

Our result showed that the availability of K and P, especially P, of the soil under the mixed stands of ash and larch was improved in comparison to that under the ash stand. This coincides with the conclusion drawn by Guo *et al.* (Guo *et al.* 1991b). The available K and P concentration of rhizosphere soil, and especially P, in the mixed stands is higher than that in Ash stand. This result shows that the availability of soil P, and K was improved with in the mixed stands, and suggests that the yield improvement effect of the mixed stand is the result of improved P and K availability, especially P availability.

The total P and K concentration of the rhizosphere zone of larch and ash was as similar as or lower than that in the off-rhizosphere zone, but the available P and K concentration of the rhizosphere soil was consistently greater than that of the off-rhizosphere soil. This suggests that the relatively high availability of P and K within rhizosphere of both tree species is not the result of higher total nutrient concentration, but the result of the activation of P and K within rhizosphere. Some other research has confirmed the activation of P and K within rhizosphere of tree (Marschner *et al.* 1986; Hinsinger *et al.* 1993; Ae *et al.* 1990; Qin and Liu 1989; Jiang 1990). The activation of P and K within the rhizosphere of larch was stronger than that of ash, and this is probably the main reason that causes the higher availability in soil of the mixed stands. Similar research was conducted with *Lupinus albus L.* and wheat, which confirmed that the yield improvement of wheat was the result of P within rhizpsphere of *Lupinus albus L.* in their mixture cropping (Gardner *et al.* 1982a, 1982b, 1983; Marschner *et al.* 1986)

The total N and available N concentration in off-rhizosphere soil in the mixed stand was similar to that in the ash stand, but greater than that in larch stand. The available N within rhizosphere soil of larch in the mixed stand was greater than that in larch stand. These results suggest that the N supplied for larch be improved in the mixed stands. But this is not the case for ash.

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